PATENT SPECIFICATION

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to Liquid Jet Reaction Propulsion Units

I, SILVIO BARLETTA, an Italian Citizen, of 11, Via Fiori Oscuri, Milan, Italy, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a liquid jet reaction propulsion unit for boats.

According to the present invention, there is provided a water jet reaction propulsion unit for a boat comprising a water intake mouth the intake plane of which is arranged flush with the keel and parallel to the proposed direction of travel of the boat at the design speed W_1 of the boat, the intake mouth forming a termination of a suction duct to deliver water to a pump impeller, which duct is generally inclined at an angle α with respect to the intake plane so that $\tan \alpha = \frac{v}{W_1}$, wherein v is the vertical componenet, taken at right angles to the intake plane, of the predetermined velocity at which the water is drawn into the suction duct and W_1 is the predetermined design speed of the boat.

Further according to the present invention, there is provided a liquid jet reaction propulsion unit for a boat comprising an intake mouth in a plane parallel to the proposed direction of travel and a duct leading from the mouth to a pump impeller, the duct axis lying at an angle α to the plane of the intake mouth and $\tan \alpha$ being equal to $\frac{v}{W_1}$ where W_1 is a predetermined velocity of the boat and v is the velocity of the water drawn into the intake mouth in a direction normal to the intake plane when the boat is travelling at the velocity W_1.

An embodiment of a reaction propulsion unit in accordance with the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawing, in which:

Figure 1 is a longitudinal section of the propulsion unit, and

Figures 2 and 3 respectively are a front view and a fragmentary longitudinal section of a detail of the propulsion unit.

Referring now to the drawing, a reaction propulsion unit for a boat or other vessel comprises an intake mouth 1, flush with the bottom of a boat and communicating through an inlet duct 2 with a pump housing 3. The housing 3 contains a conical boss 4, and blades 5 are mounted on a rotor keyed to a driving shaft 6 which passes through a seal in the wall of the duct 2 and is supported by a bearing assembly 7.

The outlet of pump housing 3 communicates with an outlet duct 8, within which a resilient vane 9 is pivotally mounted at 10. The position of the vane is adjustable by means of a screw 11 and the cross-sectional form is an arc of a circle. The outlet duct 8 ends at a frusto-conical nozzle 19 which is mounted for pivotal movement about two pivot pins 13 and 14, the axes of which are co-incident and substantially vertical. The position of the nozzle 19 can be controlled by means of a conventional steering gear in order to change the direction of a water jet issuing from the outlet duct 8, and thus to steer the boat. A portion of such steering gear consists of a spindle 20 fast with the nozzle 19.

From an operational viewpoint, the features of various components may be analyzed as follows:

The water intake mouth 1 is flush with the bottom of the boat and is parallel to

the proposed direction of travel at the design speed W_1 of the boat. Considering a water particle that at a given moment is at the middle of the intake mouth 1, it can be seen that the particle will move, with respect to the moving boat, at a relative velocity which is the resultant of two velocities, i.e. the vertical component of velocity v, due to the sucking action of the pump, and the boat velocity W_1. The direction in which the water particle is moved, is thus at an angle α with respect to the bottom of the boat, such angle being given by the relation $\tan \alpha = \frac{v}{W_1}$.

This angle determines the inclination of the inlet duct, in order that the mass of water drawn in can maintain its kinetic energy resulting from the boat movement up to the blades 5 of the pump impeller.

The velocity W_1 required for the calculation of the angle α, may be either the full speed or the cruising speed. W_1 is, in general, the velocity at which it is desired to attain the best efficiency.

In the design of the pump impeller blades 5, account must be taken not of the velocity at which the water reaches the blades, but of the velocity $\frac{W_1}{\cos \alpha}$ which is higher than W_1. Actually there are friction and other losses in the inlet duct so that it can be assumed that the water will reach the blades at the velocity W_1 in a direction parallel to the rotational axis of the impeller. Thus, the intake angle of the impeller blades 5 is designed on the basis of peripheral velocity components resulting from the rotational motion of each single point on the leading edge of each blade, and to the velocity of the water which is substantially equal to the velocity W_1.

The fact that the water reaches the impeller at a velocity similar to the boat velocity W_1 means that the water maintains the whole kinetic energy resulting from its relative motion with respect to the boat. This is essential for the purposes of high efficiency, as will be shown hereinafter by a mathematical procedure.

However, in case of boat speeds other than W_1, such calculation conditions are not always realized. Thus, to attain again the conditions of maximum efficiency, the pitch of the pump blades may be made variable, according to already well known techniques, for example by control systems as used in Kaplan turbines. Such pitch can also be reversible, when required, for reverse running.

The pump may include an axial screw impeller, or a radial centrifugal impeller, single or multiple impeller, or impellers in series.

When the invention is to be applied to special vessels, for example to hydrofoil craft, and air-cushion vehicles, the intake mouth is extended below th bottom of the vessel, whereby it can be below water level even when the hull is lifted out of the water. However, the requirements according to which the plane of the edge of the intake mouth shall be parallel to the direction of travel, and that the intake duct should be inclined at an angle alpha, as stated above, must still be met. The section of maximum penetration of the intake duct shall be such as to impose the least possible resistance to boat movement.

The jet delivered by the nozzle 19 passes freely into the air when the boat is in use.

The impeller 4,5 driven by a motor (not shown) through the shaft 6, will impart to water drawn in through the intake 1 a given momentum, as expressed by the product of mass multiplied by its velocity. Assuming that the velocity of the jet is W_2, and that Q is the pump delivery, then the thrust imparted by the jet to the boat travelling at a velocity W_1 is given by $R = \frac{\gamma}{g} Q (W_2 - W_1)$ where γ is the density of water, and g is the acceleration due to gravity. The velocity head H of the impeller is:

$$H = \frac{W_2^2 - W_1^2}{2g}$$

since the impeller receives water travelling at a velocity W_1, and delivers water from the nozzle at a velocity W_2.

The power input of the propulsion system is therefore

$$P_e = \gamma Q H = \gamma Q \frac{W_2^2 - W_1^2}{2g}$$

and the useful power available for propulsion is:

$$P_u = R W_1 = \frac{\gamma}{g} Q (W_2 - W_1) W_1$$

The efficiency of propulsion is therefore

$$\eta = \frac{P_u}{P_e} = \frac{2 W_1}{W_2 + W_1}$$

by assuming $k = \frac{W_2}{W_1}$, then the efficiency can be expressed as $n = \frac{2}{k+1}$.

It follows that as k approaches unity, i.e. the closer the jet velocity approaches the velocity of the boat, the higher the efficiency will be.

The actual efficiency is obviously lower, owing to the efficiency of the pump, the head loss in the nozzle, and other factors. Finally, the overall efficiency will be lower still owing to all resistances that are encountered while the boat is in motion.

The amount by which the jet velocity must be higher than that of the boat, to ensure the required thrust, will depend on the shape of the bottom of the boat, on the drag of the superstructure and on the speed of the boat, on which the hydraulic resistance encountered by the boat depends.

To establish the optimum jet velocity, the propulsion nozzle is fitted with the vane 9 for adjusting the outlet cross-sectional area, and consequently also the jet velocity. Such an arrangement is of fundamental importance, since it becomes possible to take due account, as a whole, of all efficiencies and losses under the practical conditions of navigation of the boat, that is, propulsion efficiency, hydraulic efficiency of the pump, head losses at the intake mouth and in the nozzle and frictional resistances of water. In other words, the outlet jet velocity giving the highest efficiency as a whole, for the boat under actual navigation conditions, can be attained.

As shown in the Figures, the above device consists of the resilient vane 9 which normally lies along the nozzle inside wall. The screw 11 by acting on the vane causes pivoting and distortion thereof. It follows that the free cross-section of the passage for the water is throttled toward the outlet end, thus effectively adjusting the outlet opening.

An outlet opening having a non-adjustable section may also be utilized, such section being experimentally determined by a preliminary test, conducted at a speed similar to that at which the highest efficiency is to be attained, or alternatively it can be calculated by taking into account of all relevant factors. With a non-adjustable outlet opening, the condition of highest efficiency will be attained only at a given boat velocity, which can be the cruising speed, the highest speed or any other selected speed.

For steering the boat, a conventional rudder would be sufficient; however resistance to travel of an order which cannot be neglected, especially at very high speeds, would be thereby introduced. Thus, the nozzle can be fitted with a device by which the jet can be deflected, thereby giving rise to a laterally-directed thrust component, by which the steering of the boat is effected. One such possible device is shown in Fig. 2, and comprises the deflector nozzle 19, pivotally mounted on the pins 13 and 14, and thus forming an extension of outlet duct. By pivoting the deflector 19 to the right or to the left by means of a pulley and cable transmission (not shown) of a conventional steering system, the jet will be correspondingly deflected.

The reversal of boat travel can be effected by deflecting the jet downwardly by an angle in excess of 90°. Moreover, advantage can be taken of the reversibility of the pump impeller, either by having the sense of rotation thereof reversed by means of a reversing switch, fitted on the motor, or by fitting the impeller with reversible pitch blades, whereby the flow direction can be reversed, while maintaining the same direction of impeller rotation.

Recourse may be had to reversal of flow direction when the nozzle is fitted on the boat transom, thus being in the air when the boat is in motion, and conversely under water when the boat stops before reversing its direction of travel. In particular, this can be obtained by taking advantage of the wake effect as caused by the boat when in motion.

Two or more propulsion systems as hereinbefore described may be fitted on the same boat, both to ensure improved stability while in motion, and to distribute the power requirements over more than one propulsion system, or finally to rely upon two propulsion systems for the normal cruising speed, and upon two additional propulsion systems for racing speeds.

Furthermore, only selected propulsion systems need be fitted with jet deflectors and reversible impellers.

In a modification, an inverted channel fitted with an impeller may be substituted for the closed inlet duct 2, such channel extending through the keel and hull of the boat. In such a case, the first part of the channel length has a slope corresponding to an angle alpha with respect to the boat bottom. The flow of water as discharged by the impeller passes out into the air from the transom which is left free of water owing to the wake effect.

WHAT I CLAIM IS:

1. A water jet reaction propulsion unit for a boat comprising a water intake mouth the intake plane of which is arranged flush with the keel and parallel to the proposed direction of travel of the boat at the design speed W_1 of the boat, the intake mouth forming a termination of a suction duct to deliver water to a pump impeller, which duct is generally inclined at an angle α with respect to the intake plane so that $\tan \alpha = \frac{v}{W_1}$, wherein v is the vertical component, taken at right angles to the intake plane of the predetermined velocity at which the water is drawn into the suction duct and W_1 is the predetermined design speed of the boat.

2. A propulsion unit according to claim 1, wherein whe napplied to a boat the hull of which is lifted from the water surface while moving at the design speed, the water intake mouth is extended downwards with respect to the bottom of the boat thereby being kept beneath the surface of the water even when the boat is moving at its design speed, and the plane of the edge of the intake mouth being parallel to the proposed direction of travel.

3. A propulsion unit according to claim 1 or claim 2, wherein the pump impeller blades are set in such a manner that the inclination is, at each point of the leading edge, the resultant of the peripheral speed at that point, and the travelling speed of the boat.

4. A propulsion unit according to any one of claim 1 to 3, wherein the impeller has variable pitch blades, thus allowing the achievement of the maximum efficiency at various operational speeds.

5. A propulsion unit according to any one of the preceding claims comprising means for maintaining the jet speed at a value which is the nearest possible to the speed of the boat.

6. A propulsion unit according to any one of the preceding claims, comprising a nozzle with an adjustable outlet orifice whereby the optimum jet outlet speed can be maintained, due account being taken of all efficiencies under the actual conditions of boat navigation.

7. A propulsion unit according to any one of preceding claims 1 to 5, comprising an outlet nozzle having a fixed section, such section being determined experimentally or by calculations, in order to produce a jet speed giving the maximum efficiency.

8. A propulsion unit according to any one of the preceding claims, comprising a nozzle pivotal about a vertical axis, by which the jet can be deflected to the right or to the left, whereby the boat can be steered.

9. A propulsion unit according to any one of claims 4 to 8, wherein the direction of motion of the boat can be reversed by reversing the pitch of the impeller blades.

10. A propulsion unit according to any one of the preceding claims, comprising a deflector for deflecting the jet downwardly, at an angle in excess of 90 degrees with respect to the horizontal, in order to reverse the direction of motion of the boat.

11. A propulsion unit acording to any one of the preceding claims, wherein the jet nozzle is fitted in a position such that it is under water when the boat is still, or is moving in reverse, and in air when moving in the forward direction.

12. A propulsion unit according to any one of the preceding claims, wherein the duct has the form of a channel having an open bottom, the propulsive jet being ejected to the air adjacent the transom, which is kept free due to wake effect of the boat.

13. A liquid jet reaction propulsion unit for a boat comprising an intake mouth in a plane parallel to the proposed direction of travel and a duct leading from the mouth to a pump impeller, the duct axis lying at an angle α to the plane of the intake mouth and $\tan \alpha$ being equal to $\frac{v}{W_1}$ where W_1 is a predetermined velocity of the boat and v is the velocity of the water drawn into the intake mouth in a direction normal to the intake plane when the boat is travelling at the velocity W_1.

14. A propulsion unit substantially as hereinbefore described with reference to the accompanying drawings.

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1,063,945 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.